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TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA
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The Present Status of Climatic Change in the Atlantic Sector of Northern Seas, with Special Reference to Canadian Eastern Arctic Waters

M. J. DUNBAR, F.R.S.C.

IT is generally assumed that the world is either just coming out of an ice age which has consisted of four major periods of polar glaciation, or is still in the middle of an ice age and between two periods of glaciation; but there is a good deal of argument about which is the correct alternative. Apart from making allusion to the recent work of Wiseman (1954), with its strong indication that the trend in Atlantic surface temperatures since the climatic maximum of some 5000 years ago has been downward, relieved only by smaller aberrations of the curve, it is not my purpose here to discuss the matter of the longer-term trend, but to draw attention to certain aspects of the shorter cycle of variation in the sea, with reference to the North Atlantic and especially to the eastern arctic of Canada.

It has been known for some time, and it has recently been reaffirmed by Jung (1952), that "in polar regions there is a net radiation of energy into space from the earth and from its fluid envelope. . . . In tropical regions these [the earth and its envelope] receive a net excess of solar radiation." In spite of this, there is neither sustained cooling at the poles nor sustained warming in the tropics. There must therefore be "a poleward transport of energy through the earth's fluid envelope."

We are concerned here with only the liquid part of that fluid envelope, the ocean, which, although it may play a lesser role as a transporter of energy than does the atmosphere (Sverdrup's [1942] estimate is only 10 per cent for the seas against 90 per cent for the atmosphere), nevertheless is clearly heavily involved in the climatic cycle, the more so because of its much higher specific heat and lower velocity of transport, which give its action in this respect greater staying power than the atmosphere and an important steadying effect. Without this steadying effect of the sea, climatic change would be a sudden and rather violent affair.

Variations in the intensity of the poleward transport of energy constitute the variations in climate of the shorter cycles (from, say, 400 years to 15 or 20 years) which are superimposed upon the long-term cycles of several thousands of years. In the North Atlantic marine, it is the Gulf Stream-Atlantic Drift system which effects this transport, and there is plenty of evidence that during the past thirty years, from about 1920, the northward flow has increased both in volume and in temperature (Jensen, 1939; Con-

seil, 1949). This has resulted in the now well-known and much discussed warming of the waters of west Svalbard (Spitsbergen) and west Greenland, and also of the Barents and Kara Seas, with the concomitant northward extension of the distribution of marine animals, many of them of great economic importance, such as the Atlantic cod (*Gadus callarias*), the herring (*Clupea harengus*), and even the Atlantic salmon (*Salmo salar*). The number of species affected is enormous; in fact, what has happened is a movement northward of the subarctic region of high productivity. The increase in transport of the Atlantic water may also have affected the inland sea of Hudson Bay (Bailey and Hachey, 1951) and has certainly had its effects on the Canadian Atlantic seaboard (McLellan, 1955), but the warming of the Canadian waters has been very much less pronounced than in west Greenland and in Spitsbergen, for reasons suggested below.

In this process of increased Atlantic Drift activity, as in most changes in nature, there has been an element of self-regulation, or of a mechanism whereby the effects of the change are damped by processes set up by the original event itself. An increased flow of Atlantic water northward to the Arctic Ocean requires an increased flow of polar water southward, so that the two areas most influenced by the polar outlets—east Greenland and the Canadian eastern arctic—must have been buffered against the marine climatic change; and it is in fact in those two areas that the climate has changed least in the whole of the North Atlantic region in the past thirty-five years. Thus any warming effect in those two regions would not be expected to bear a simple or direct relation to the increased volume, velocity, or temperature of the Atlantic Drift circulation.

Since first pointing out this element of self-regulation in the system (Dunbar, 1954), which is in fact little more than the extension to the marine environment of the phenomenon of intensified circulation already described for the atmosphere by Vize (1935), Scherhag (1937) and others, I have found a Russian paper by Berezkin (1937) which describes the same developments in somewhat different terms for the circulation of the Greenland Sea, that is to say for the relation between the Atlantic Drift water flowing northward to Svalbard and the polar water of the East Greenland Current. The Russians have found that an increase in flow in the Atlantic current of the eastern Greenland Sea is accompanied, or followed very shortly, by an increase in the flow of the polar water of the East Greenland Current; this applies both to volume and to velocity. And there is also a relation between the temperatures of the two water masses, in this case an inverse one. In the years 1933–35, it appeared that 1933 and 1934 were years of less intense circulation in the Greenland Sea than was 1935, and in a section along the 80th parallel the Atlantic water was 0.4° to 0.5°C. higher in 1935 than in 1933 and 1934, while the East Greenland water was 0.5° to 1.0°C. lower. The dates of observation are not given in the translation available of Berezkin's paper (Air Force Cambridge Research Centre, 1954), but presumably they were made at the same time of year each year. There was also

a slight increase in the salinity of the Atlantic water in 1935, and a decrease in salinity in the East Greenland water.

Summing up these observations, Berezkin writes: "Assuming that the quantity of the water masses in the Polar Basin remains constant from year to year, it may be inferred that an increase in the intensity of the Atlantic Drift would inevitably bring about a similar increase in the Polar Current that runs counter to it, and vice versa. As a result, the whole circulation process of the waters of the Polar Basin is expressed more intensely." He also emphasizes a very practical result of his studies in that "increased temperature of the North Cape Current in August of any year is reciprocated by a greater amount of ice in the Greenland Sea in July of the following year."

An important point which Berezkin does not mention is that as the velocity of a current increases, so does the Coriolis force acting upon it. This means that in the Greenland Sea the Atlantic water will be pressed more strongly to the east and the East Greenland water more strongly to the west, against the Greenland coast; again the fact is emphasized that the stronger the Atlantic flow the greater the buffering effect of the East Greenland Current against marine climatic change in east Greenland.

The same principles apply in exactly the same way to the Canadian eastern arctic region, where the Atlantic component is the Atlantic water in the West Greenland Current, which is formed of East Greenland polar water, Irminger Current (Drift) water, and Atlantic water from the Labrador Sea, and the polar outflow is the Canadian Current along the coast of Baffin Island, forming part of the Labrador Current south of Hudson Strait. From the fact that the warming in west Greenland has been synchronous with the west Spitsbergen warming, we may deduce what we might expect in the first place, namely that as the flow of Atlantic water in the Greenland Sea increased, so did the flow in the Irminger Current, and, since the increased Atlantic flow in the Greenland Sea induced increased flow in the East Greenland polar current, we must assume that the Irminger effect in west Greenland was that much the greater, resulting in the balancing and surpassing of this increased polar current flow which forms part of the West Greenland Current.

As the West Greenland Current grew warmer, then, it is to be expected that the Canadian Arctic Current (Baffin Island Current) would increase in intensity of flow. This would make it more difficult for West Greenland water to penetrate into Hudson Strait, by the simple buffering effect of the greater amount of polar water flowing into and across the mouth of the Strait. Furthermore, the increased intensity of circulation, in particular the greater velocity of the West Grenland Current, would cause that current to be pressed more strongly against the Greenland coast, thus inhibiting or reducing the amount of West Greenland water that turned off to the west south of the Holsteinsborg ridge. It is already known that the transport of the West Greenland Current varies from year to year and that the extent to

which it holds close to the Greenland coast is proportional to the transport (Kiilerich, 1943).

Such a mechanism, if it has been correctly interpreted, explains the striking contrast between the degrees of marine climatic change on the two sides of Baffin Bay, Davis Strait, and the Labrador Sea. In west Greenland it has been drastic, in the Canadian eastern arctic very slight, if indeed there can truly be said to have been any change, except perhaps very recently on the Labrador coast. The interpretation also leads to an important conclusion which might help us to understand what is happening in this climatic cycle at present and how it has operated in the past, at least as regards the most proximate of the causes involved. At those points in the cycle when the poleward energy transport of the Atlantic Drift system is just beginning to pick up momentum after a slack "trough" period, or is just beginning to relax after a peak of intensity, the flow of Atlantic water, although not maximal, would be countered by a less than maximal flow of polar water in the circulation, and, moreover, it would be subject to a lesser geostrophic force than at peak intensity. Hence the relative effects of the Atlantic influence on the two sides of Baffin Bay and Davis Strait would not be the same as at the peak in the cycle; the effect on the western (Canadian) side would be relatively stronger, and might well be absolutely stronger than the warming effect on the same western side during peak years. The same rules would apply at the peaks of lesser cycles as on the slopes of the greater cycles.

The working of this system appears to have been illustrated during the late 70's and early 80's of the last century. During that period there was a minor peak in the water temperatures in west Greenland (Smed 1949, Dunbar 1946) which, however, was very much less in degree than the recent peak there, and without the accompanying large-scale immigration of Atlantic cod. There was a similar warming in west Spitsbergen, as would be expected, which disappeared again in 1883 or 1884. But there is evidence that the Canadian eastern arctic, and in particular Ungava Bay, experienced an increase in marine temperatures at that time greater than anything that is happening there at the present or in the recent past. From 1882 to 1884, Lucien Turner, on a commission from the United States Corps of Signals, worked at Fort Chimo as one unit in the International Polar Year Expedition of 1882. Much of his work during that time has not been published, and there do not appear to have been any observations of sea temperatures, but his manuscript report on the fishes collected[1] records that the Atlantic cod was moving northward at that time "even to far north of Cape Chidley," and that the caplin (*Mallotus villosus*) was also moving northward year by year and into Ungava Bay. On the subject of the caplin he writes: "Within Hudson Strait they had not been detected until several years ago when a few were seen in the neighbouring waters of George's

[1]The author is indebted to the Smithsonian Institution for the loan of Mr. Turner's manuscript on the fishes of Ungava Bay, and of his caplin specimens.

River. In the spring of 1884 they were observed in great numbers in that vicinity. On the 8th of August 1884 a school of several thousand individuals appeared four miles within the mouth of the Koksoak River. As many as were desired for specimens were secured by the hand as they swam near the shore. . . . This is the first instance known either to whites or natives of the appearance of the Capelin in the southern portion of Ungava Bay."

The caplin is a subarctic fish with a narrow north-to-south range of distribution, common in Newfoundland and southern Labrador, and in west Greenland, where its centre of distribution has been pushed northward in the last thirty years. It is a very conspicuous species owing to its habit of swarming in great numbers close in to the shore during the breeding season. It is at present almost entirely absent from Ungava Bay. During four seasons of field work in Ungava from 1947 to 1950, the *Calanus* expeditions, using dredges, trawls, handlines and stramin plankton nets, took only two young specimens of the caplin, and none was found in the stomachs of seals or of the Atlantic cod (Dunbar and Hildebrand, 1952). The temperatures measured in Ungava Bay were somewhat low for the normal caplin range, being never above 5.8°C. at the surface nor above 2.5°C. at 10 metres.[2]

On this biological evidence alone it must be supposed that the marine climate of Ungava Bay at that time was milder than it is at present, at a time when the west Greenland climate was only at a minor peak, much less intense and prolonged than the more recent cycle including these present years. The presence of Atlantic cod in Ogac Lake, a salt-water lake on the shore of Frobisher Bay (Dunbar, 1952), may also be relevant. The locality lies over one hundred miles from the northernmost present occurrence of the cod (Resolution Island), and the cod is not found in the waters of Frobisher Bay itself. The lake population lives there all year round and shows the characteristics of warm-water cod. (The lake water is much warmer than the fjord water outside.) It is clear that they must have reached the lake during a former period of warmer climate. The 1880 period is the most likely, for the lake is very small and the survival of an isolated cod population in so confined a habitat for longer periods of time is not probable.

There are relics of a warmer climate at present living in Hudson Bay. The caplin itself is common, at least in the southwestern part of the bay, and the copepod *Acartia clausi* is known from James Bay and southern Hudson Bay. This species is an Atlantic form, known from southern Labrador, Gulf of St. Lawrence, southern Iceland, Norwegian coast, and southward to west Africa (Jespersen 1934). It is not recorded from west Greenland. As in the case of the cod in Ogac Lake it is questionable whether

[2]Tuck and Squires (*J. Fish. Res. Bd. Canada*, XII, no. 5) have reported caplin to be fairly common in the stomachs of Brünnich's murre (*Uria lomvia lomvia*) on Akpatok in 1954. The caplin specimens were all young, none over two years of age. It is possible, though not certain, that this demonstrates a movement of caplin into Ungava Bay within the past three years.

these could reasonably be supposed to have survived several thousand years since the last major climatic maximum; it is more likely that they are relics of a much more recent warming.

So much for the 1880's. The warming of more recent decades, which has affected west Greenland so strongly and the Canadian waters so much less, now appears to have come to a standstill in Greenland and to be on the wane farther to the east. There is no evidence of warming in the West Greenland water beyond the middle 1930's, and during the 1942–4 period there was a suggestion of slight cooling at the level of Godthaab (Dunbar, 1946). Hansen (1949) considers that a peak was reached in 1934, but that the temperatures since then have not given reason to suppose that the warm period is about to end. Temperatures have maintained the same level up to the present date, but there have been one or two cold years which have done some damage to the cod fishery, enough to cause Hansen and Hermann (1953) to write that "after 1935 water temperatures dropped a little." East of Greenland, in the section between Greenland and the Faeroe Islands themselves, water temperatures have been falling, starting in the late 1940's (Taning, 1953). In the atmosphere there is the same record of a drop in temperature at the present time (Ahlmann, 1953).

A relaxation of the Atlantic Drift circulatory system would in fact be expected to make its effect first known in this northeastern area, since it is the area most distant from the origin of the current; and if the reasoning presented here is correct, then it is at this time and in the next few years that we might look for some warming of the marine climate in the Canadian eastern arctic, especially from Hudson Strait southward. It is possible that cooling on our eastern shores will not occur until the whole circulation enters a "weak" phase, that is, one in which the energy loss in polar regions is not adequately balanced by energy transfer from the tropics.

Discussing this problem of changes in hydrography in the arctic, sub-arctic and temperate parts of the Atlantic Ocean, Taning (1953) writes: "Owing to the influence of these changes on the fluctuations in certain very important fish stocks, they present the most important general problem of present day fishery investigations in the said ocean areas." With this in mind, it is appropriate here to make a plea for much more detailed annual routine observations in the Canadian northern waters than we are at present making. For instance, we have no way of knowing whether the Canadian Arctic Current has in fact been changing in temperature and intensity as the East Greenland Current appears to have been doing, because the necessary observations have not been made. The same applies to the Labrador Current. Only by constantly building up our knowledge of the year-to-year process can we obtain a picture of the pattern of change; without that picture we can do little more than speculate on the forces at work, as I have been doing here, with the necessity of using interpolations in a spare network of facts, interpolations which may seem at times to be somewhat extravagant. The pattern is certainly not simple; it is a dynamic process

and contains elements of self-regulation, feed-back, and controlled oscillation which cannot but be very difficult to grasp without a large and growing body of measurements and observations.

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Annual Variation in Pressure and Surface Winds over the Atlantic, between Labrador and Greenland[1]

J. G. POTTER

THE main wind systems of the world are one of the forces driving the surface currents of the oceans. The custom of including both surface currents and wind systems on one chart, or adjacent charts, in an Ocean Atlas indicates that a knowledge of the general wind circulation is necessary for an understanding of the currents.

Because of the close relationship of the general circulation of the air and the distribution of the mean air pressure, it is more convenient to begin with the latter. The spacing and general pattern of the lines of equal pressure, or isobars, indicate the speed and direction of the mean flow of the air above the friction layer. Surface winds will be slightly weaker, and will blow across the isobars towards the lower pressure at a small angle whose size depends upon the size of the frictional forces.

Knowledge of the distribution of the mean pressure over the world has increased during the past century with the increase in data available. Buchan (1869) was able to publish a paper on "The Mean Pressure of the Atmosphere and the Prevailing Winds over the Globe, for the Months and for the Year." Shaw (1936), Brooks and Connor (1936), and the United States Weather Bureau (1952) are among those who have published mean pressure maps since that time. The chief improvement in these later maps is the refinement of detail possible with the greater data available. The pressure data used for Figs. 1–4 are based mainly on the ten years 1940–9. During the early part of this period many meteorological observing stations were established by Canada and the United States in this region. Ocean weather ship position "Baker" was established at 56° 00′ N, 51° 30′ W. By confining the charts to a small region, and because of the greater amount of data available, it has been possible to show the mean pressure distribution in finer detail than it has been drawn on the charts referred to above.

By an analysis of the wind data from various observing stations in this region it is now possible to indicate the frequency of winds from various directions and their mean speeds at these points. In each wind rose (Figs 1-4) the number in the centre of the inner circle shows the percentage of time when the wind was calm. The percentage frequency of the direction of the wind to eight points of the compass is represented by a line, proportional in length to that percentage, and extending out in the direction

[1]Published with the permission of the Controller, Meteorological Services of Canada.

from which the wind blows. The outer circle indicates the $12\frac{1}{2}$ percentage level. The numbers at the end of each of these percentage frequency lines gives the mean speed (m.p.h.) of the winds from that direction.

All wind data, in regard to both direction and speed, are influenced to a great degree by the local topography of the observing site. At Simiutak, near the mouth of a long fiord near the southern tip of Greenland, the winds blow along the fiord or the coastline. At Cape Harrison, high hills obstruct the wind flow from the east and from the southwest quadrant. The observing site on Padloping Island is near the base of a 500-foot cliff which protects it from westerly winds. At Resolution Island there are hills near the observing site, but more important is the tendency for winds in this area to blow from the west or east along Hudson Strait. Only at Weather Ship Baker are the winds observed under conditions where it may be felt with some confidence that the data are representative of conditions over a wide area.

Owing to the extensive computations necessary to assemble the wind

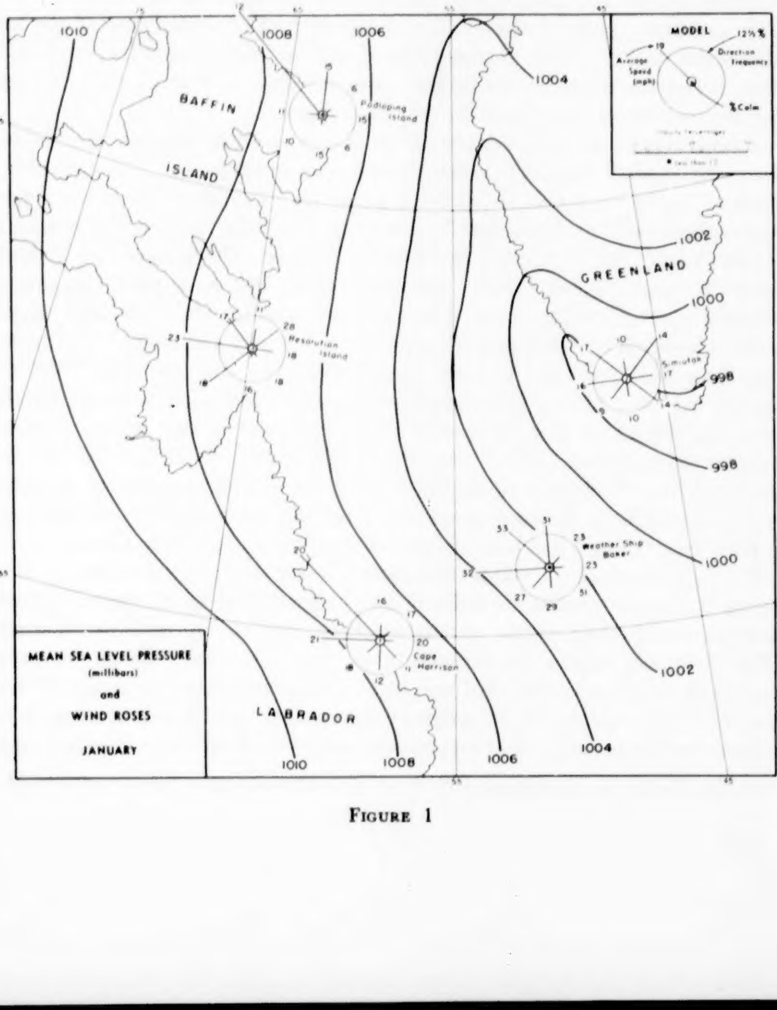

FIGURE 1

data it was found impossible to use a uniform period. Most data are for eight to ten years, with the exception of that for Weather Ship Baker which are based on the four years 1948–51 inclusive.

The general circulation in this region in January is under the influence of the Icelandic Low. Fig. 1 shows a trough of low pressure from this low extending northwestward along the Greenland coast. West of this trough the isobars indicate that the direction of the mean flow is from the north and northwest, and that the mean flow is strongest over the waters between Labrador and Greenland. The wind rose at Weather Ship Baker confirms how often the wind direction over this section of the ocean is from the west, northwest, and north (about 70 per cent of the time in this region) and how strong this flow is. The average speed of the winds from all directions in January is 31 m.p.h. During the four Januaries for which data are available the wind at this ship did not exceed Beaufort force 11 (65–74 m.p.h.) but reached this force during 1.2 per cent of the time.

Along the coast of Labrador and Baffin Island the influence of the local

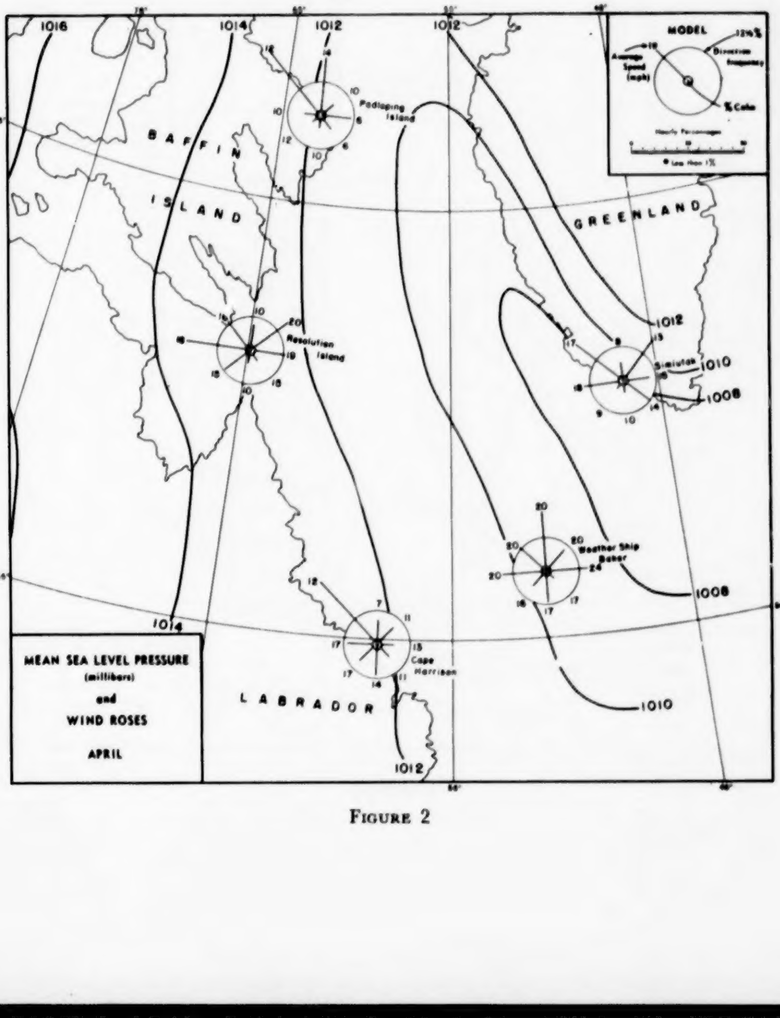

Figure 2

topography of the observing site may cause direction frequencies that do not fit the general pattern. At Cape Harrison and Padloping Island the predominance of northwest winds is striking. At Resolution Island the wind rose indicates the effect of the site at the entrance to the Strait. Where the trough in the mean pressure pattern along Greenland is the result of changes in daily pressures, the wind directions are much more variable. At all shore stations the wind speeds are lighter than at Weather Ship Baker—the result of weaker pressure gradients and greater friction.

Conditions in April (Fig. 2) reveal seasonal changes that result in an almost complete reversal of the direction of the general circulation during the next three months. The trough of low pressure southwest of Greenland begins to broaden and move off the coast. There are indications of another trough forming southeast of Weather Ship Baker. This later trough becomes much more pronounced and moves westward to central Quebec during the next two months. The wider spacing of the isobars suggests that the mean

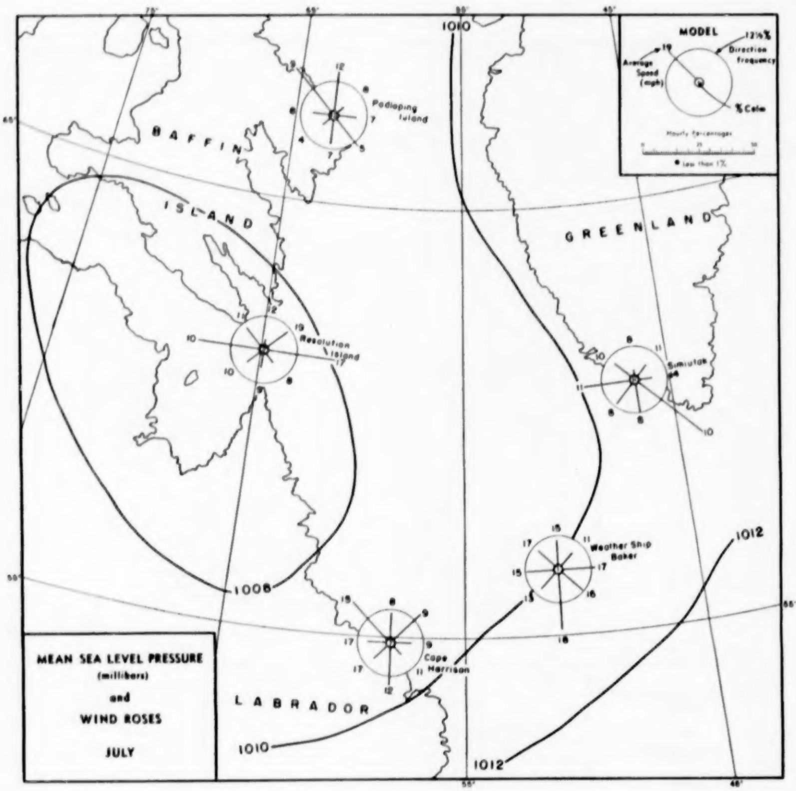

Figure 3

wind flow is becoming more variable and lighter. This is confirmed by the wind data. At Weather Ship Baker the occurrence of winds between west and north is not as frequent as in January. The frequency of easterly and southerly winds shows a great increase, while the mean speed of all winds has decreased to 20 m.p.h. In the other wind roses, where the mean circulation is still from the northwest, similar changes from January conditions are noticeable.

The general circulation in July (Fig. 3) shows the greatest departure from that in January. With a low pressure area in the vicinity of Hudson Strait the prevailing flow over the waters near the Labrador coast is from the southwest. Farther off shore it backs to southerly, and then to southeasterly near the Greenland coast. There is a corresponding rise in the frequency of the winds from these directions at Cape Harrison, Weather Ship Baker, and Simiutak. The mean wind speed at Weather Ship Baker in July is 16 m.p.h.

In September and in October (Fig. 4) the mean pressure pattern is in

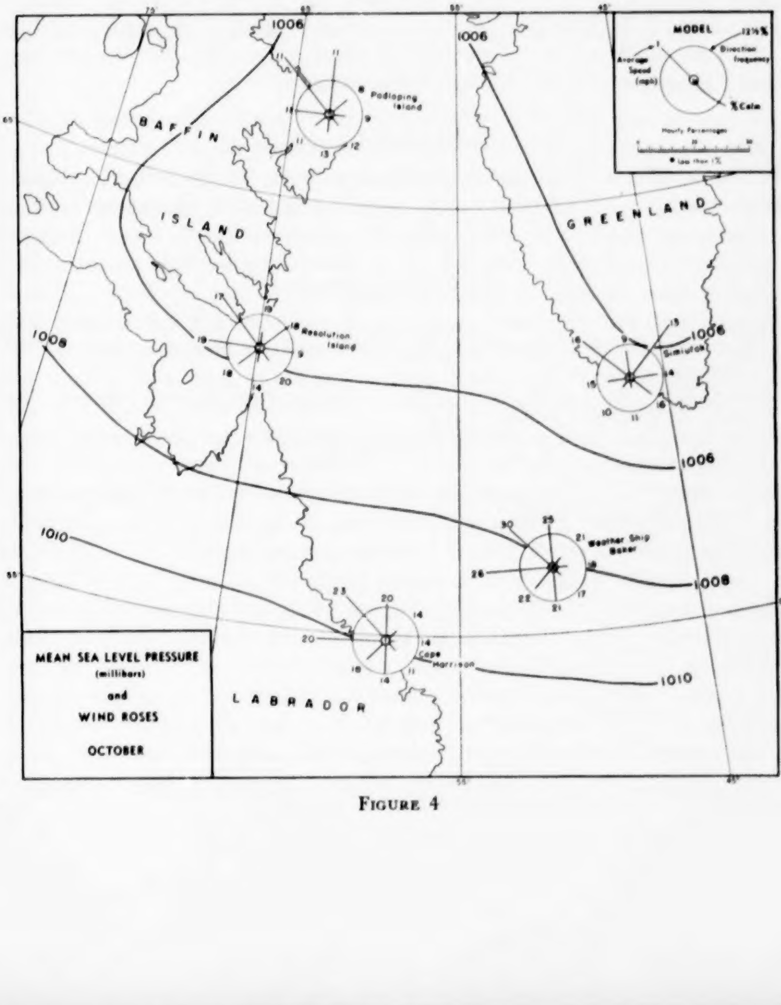

FIGURE 4

the process of reverting to the winter pattern. In October there is still evidence of a weak low which has shifted northeastward from the July position and is now centred between southern Baffin Island and Greenland. South of this low the mean circulation is strong westerly. There is still considerable day to day variation in the wind direction as the wind rose at Weather Ship Baker indicates, and the winds are much stronger than in July. The average wind speed for October at Weather Ship Baker is 26 m.p.h., only 5 m.p.h. less than in January. Along the Labrador Coast at Cape Harrison, and also at Resolution Island, there is also a large increase in the frequency of occurrence and the mean speed of winds from the west and northwest.

The meteorological data presented here may be useful in deducing the mean ocean currents and probable variations of these currents (and ice movement) throughout that part of the year for which direct observations of such phenomena are lacking. While Figs. 1–4 contain data based on only four of the twelve months, it is possible to group the remaining eight months through their similarity to these four. Thus January is typical of winter conditions which extend from November to March inclusive. Summer conditions, from June to August, are similar to those in the figure for July. The transitional seasons of spring and autumn are each two months long, and a figure for each of these seasons is included.

Acknowledgment

The author is indebted to the United States Weather Bureau whose National Weather Records Center provided valuable summaries of some of the wind data.

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Climatic Trends along the Atlantic Coast of Canada[1]

M. K. THOMAS

Introduction

CLIMATIC change has been a popular subject for discussion by meteorologists, astronomers, oceanographers, and other scientists during the past several years. Although scientists do not always agree about the various theories concerning the causes of these changes, practically everyone does agree that there has been a general warming up of much of the Northern Hemisphere during the past twenty years. In this study of climatic trends along the Atlantic coast of Canada attention is focused on the temperature records of stations from Yarmouth, N.S., northwards along the Newfoundland and Labrador coasts to Clyde on Baffin Island.

Southeast Coast

In an earlier paper Longley has shown that during the past seventy-five years there has been an increase of annual temperature throughout eastern Canada. In the Atlantic provinces the decade of the 1880's was cold, followed by rapidly warming conditions in the 1890's. The ten-year moving mean of annual temperatures then remained fairly constant for two decades but reached a secondary minimum in the decade ending about 1925. From that time until the early 1950's there has been, in general, a rising trend in temperature.

The Meteorological Service of Canada has maintained weather reporting stations at coastal locations in Nova Scotia and Newfoundland since 1873. However, some of these early station records are not complete, and other stations were not equipped with maximum and minimum thermometers in the early years. Not until 1891 do we have continuous, fairly homogeneous data from Yarmouth, Halifax, Sydney, and Sable Island. While there have been significant changes in location at all of these stations except Sable Island, the data appear remarkably homogeneous and there does not appear to be a break in the record at any of these four stations.

To enable examination of the temperature régime along Canada's southeastern Atlantic coastal area, the records from those four stations have been combined. Ten-year moving means have been computed on an annual basis, and also for the winter and summer seasons. The winter season was taken to consist of December of the previous year and January and February. Data for June, July, and August were used for the summer season.

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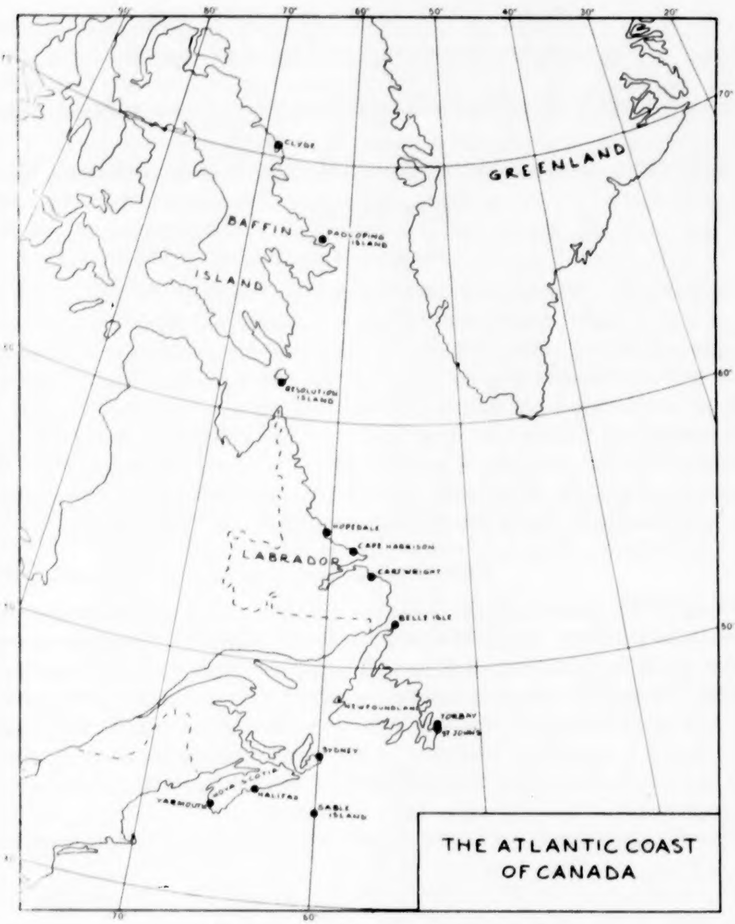

FIGURE 1.—The Atlantic coast of Canada.

The trend of annual temperatures shown in Figure 2, where the mean for each decade is credited to the mid period, indicates a slow decrease from 44.3°F in the 1890's to 43.1°F in the early 1920's. The trend was rather sharply upwards during the late 1920's to 44.6° in the early 1930's, then levelled out until another sharp increase took place in the late 1940's. The most recent decade of 1945 to 1954 has a mean temperature of 45.3°, the highest decadal mean in the sixty-four years under review. Decadal average annual temperatures have thus increased by more than 2° during the past thirty years. Referring back to Longley's paper, it can be seen that the decadal mean for these stations probably was as low as 41.5°. This indicates an increase of nearly 4° in mean annual temperature along the southeastern Atlantic Coast from 1880 to 1954.

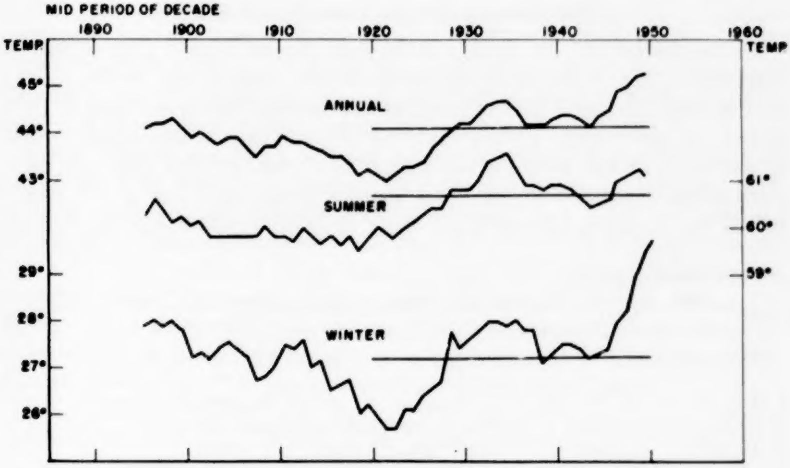

FIGURE 2.—Temperature trends on the southeast Atlantic coast of Canada; ten-year moving means of temperature at Yarmouth, Halifax, Sydney, and Sable Island, credited to the mid period of each decade.

Looking at data for the summer season, it can be seen that the trend of temperature change has been much the same as that on an annual basis. The warmest summer on record was 1937 and four of the seven warmest seasons occurred in the decade of the 1930's. Mean summer temperatures averaged just above 60° in the 1890's and then just less than 60° until 1920. Temperatures then increased rapidly to 61.6° in the early 1930's. Temperatures were then lower with the decadal mean dropping to 60.4° in the mid 1940's before increasing again to 61.2° just prior to 1950. It should be noted that mean summer temperatures in the 1930's were greater than at present.

Winter temperatures have been more variable than summer temperatures. From 1891 until the current year the actual winter means combined from the four stations have varied from a low of 21.5° in 1923 to 33.8° in 1951—a range of more than 12 degrees. Decadal means for the winter season decreased from 28° in the 1890's to 25.6° in the early 1920's. A secondary maximum of 28° was again reached in the early 1930's followed by a short decline and then a further increase to the maximum of 29.8° for the decade ending with the winter of 1955. The decadal means have shown an increase of four degrees during the past thirty years.

Figure 3 illustrates the temperature trends at Sable Island. As mentioned above, the records from this island station correspond closely to those from mainland stations. Annual temperatures at Sable Island average about one degree more than the combined values of Yarmouth, Halifax, Sydney and Sable. Winter temperatures are 4.5° more and summer temperatures 2° less than the combined values from the four stations.

Newfoundland and Labrador Coast

In Newfoundland, St. John's is the only station with a long period of temperature data. Temperature trends at this station agree well with the data already discussed for the Nova Scotia stations during the period 1891 to 1941. Unfortunately a break occurred in the records of this station during World War II and data for the past fifteen years are not available on a comparable basis. There are other stations along the coast of the island which have been in operation for more than thirty years, but on account

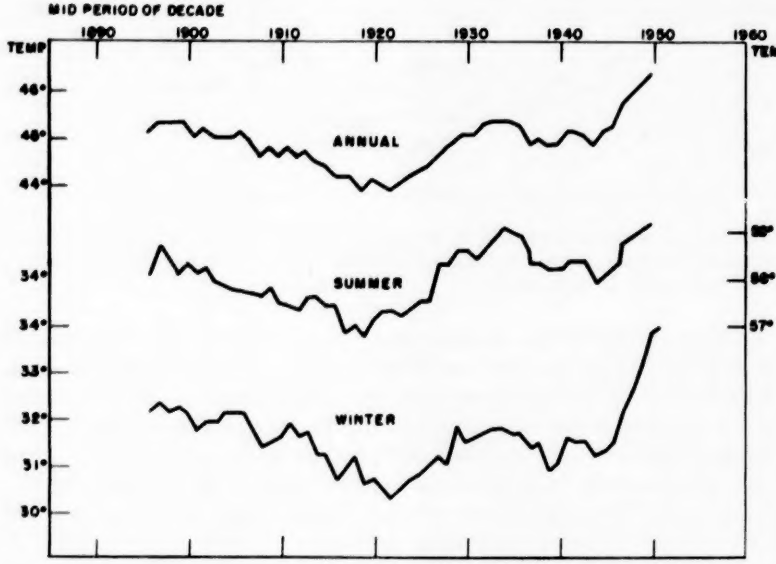

Figure 3.—Temperature trends at Sable Island; ten-year moving means of temperature credited to the mid period of each decade.

of missing data and short periods of in-operation there are no additional data which lend themselves to this study.

During the last century the Moravian Missionaries recorded weather data at a few locations along the Labrador coast but the available periods of record are not long enough to be of use here. Data from stations established by the Meteorological Service during the 1930's and 1940's are shown below.

Resolution Island

In the late 1920's, with the establishment of the Hudson Bay shipping route, a weather reporting station was set up at Resolution Island. Data from this station have been available since 1929 and moving means have been computed on an annual, winter, and summer basis; these are shown

in Figure 4. As pointed out by Longley, the decadal means of annual temperature at Resolution Island show somewhat the same trend as those for southeastern Canada. It should be noted, however, that the maximum ten-year mean of annual temperature occurred in the mid 1940's and this value has not yet been reached again in the current warm spell.

While decadal means of summer temperature have been increasing in recent years at Resolution Island, they have not yet reached the peak established during the first ten years of record. Since 1929 mean winter temperatures have varied from —5° in 1935 to 12° in 1947. The latter year may be remembered as the winter with exceptionally warm February temperatures in the northern Quebec region. At Resolution Island the winter trend was sharply upward during the 1930's reaching a maximum in the mid 1940's. Since then the winter season temperature trend has shown a decrease.

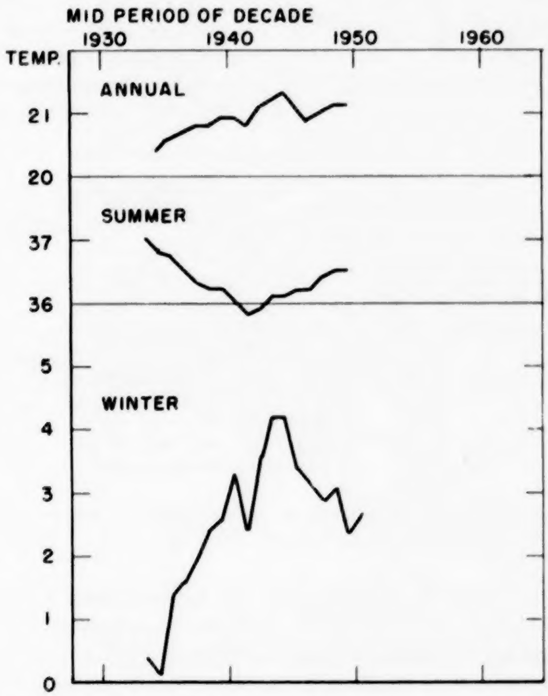

FIGURE 4.—Temperature trends at Resolution Island; ten-year moving means of temperature credited to the mid period of each decade.

RECENT TEMPERATURES

Figure 5 has been prepared in order to allow closer examination of the temperature trend during the past fifteen years. The actual annual tempera-

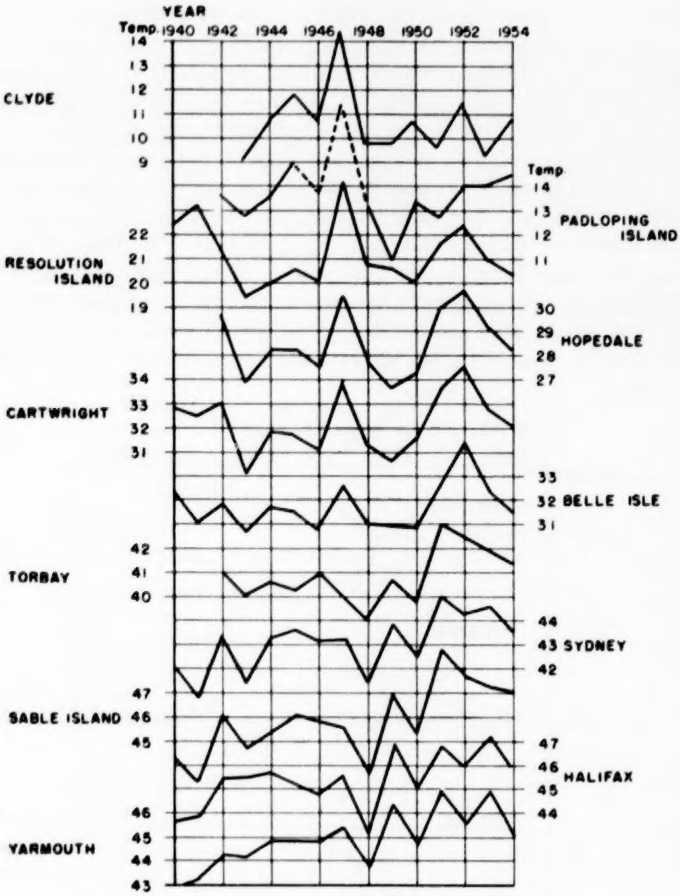

FIGURE 5.—Annual temperatures along the Atlantic coast of Canada, from Yarmouth, N.S., north to Clyde, N.W.T., for the period 1940–1954.

tures shown represent 11 stations along the Atlantic coast from Yarmouth northward to Clyde, some of which were not in operation in 1940. Data were estimated for Padloping Island in 1946 and 1947.

It is evident that these temperature profiles may be divided into northern and southern groups. The southern group from Yarmouth northwards to Torbay show a steady or slightly increasing trend in annual temperature from 1940 until the cold year of 1948. The warmest year was 1951 followed by a decreasing temperature trend except at Halifax and Yarmouth where the temperature profile has a sawtooth appearance for the past six years.

The northern group, from Belle Isle northward along the Labrador and

Baffin Island coasts, has a different type of profile. The early 1940's were comparatively warm but the following years were colder until the already mentioned exceptionally warm year of 1947. This warm year was most pronounced along the coast of Baffin Island. Another warm year was experienced in 1952; 1953 and 1954 have had lower temperatures, especially along the Labrador Coast.

Summary

Temperature data from the coastal areas of Nova Scotia and Newfoundland indicate a warming trend during the past sixty-five years. Decadal means of annual and winter temperatures are currently at their maximum for that period and show increases of 2 and 4 degrees respectively during the past thirty years. Although summer temperatures were at their maximum in the early 1930's they are now averaging almost 2 degrees higher than just prior to 1920. The warming trend is evident at Resolution Island, but is not nearly so pronounced. Trends along the Labrador and Baffin Island coasts are probably similar to those at Resolution Island and these stations show greater year to year variation than those on the southeastern coast of Canada.

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